MINERVA: Using Small, Fully Robotic Telescopes to Search for Habitable-Zone Exoplanets

Completed Technology Project (2013 - 2016)

Project Introduction

The 2010 Decadal Survey of Astronomy and Astrophysics declared that a program to identify nearby, terrestrial planets with the possibility for liquid water and oxygen in the atmosphere is of top priority. Finding these planets poses significant technical challenges. Firstly, nearly all current instruments lack the sensitivity to detect habitable-zone planets with masses less than five times that of Earth's. Secondly, a planet's radius and mass, and thus its density and internal composition, can only be estimated through the combined data from both transit and radial velocity measurements. Thirdly and most considerably, definitive detection of such planets requires the observations of many orbits in order to obtain a time-averaged signal. This level of cadence is unfeasible in the existing framework of shared telescope time, and currently there are few observatories dedicated to exoplanet science. The Minerva project will address these limitations by building a ground-based telescope array, capable of both transit science and radial velocimetry, dedicated to the detection of terrestrial planets around nearby stars. Four 0.7-meter telescopes will each be equipped with an imaging camera and will fiber-feed to a single high-resolution spectrometer. The multi-telescope model affords Minerva the flexibility to observe in formation, with a synthesized aperture of 1.4m, or take simultaneous spectroscopic and photometric measurements. Perhaps the most unique feature of Minerva will be its availability to search for planets every single clear night. To accomplish this, the observatory will be fully robotic; all components of the telescope array and instrument suite will need to operate autonomously. The Minerva software will control multiple telescopes and a number of instruments simultaneously, requiring precise synchronization and complex data handling. The system must be robust and efficient in recovering from any errors encountered. My task is to lead the design of the Minerva software, thereby solving the problem of how to efficiently and robustly manage a complex distributed-aperture robotic observatory with an extensive instrument suite. I plan to base the software architecture on the modular and highly efficient model developed for Robo-AO, a successfully operating fully robotic adaptive optics system. I have personally developed routines for Robo-AO and hope to adapt the system to meet Minerva's unique requirements. Minerva will directly address a multitude of technical challenges put forth by NASA's Space Technology Roadmaps. Firstly, the distributed-aperture model is immediately matched to TA8.2.3: Distributed Aperture Observatories. Secondly, the complex robotic system will necessarily advance technologies in the field of autonomy, specifically the following areas: TA4.5.4: Multi-Agent Coordination, TA4.5.2: Dynamic Planning and Sequencing Tools, and finally TA4.5.3: Autonomous Guidance and Control.

Anticipated Benefits

The 2010 Decadal Survey of Astronomy and Astrophysics declared that a program to identify nearby, terrestrial planets with the possibility for liquid water and oxygen in the atmosphere is of top priority. Finding these planets

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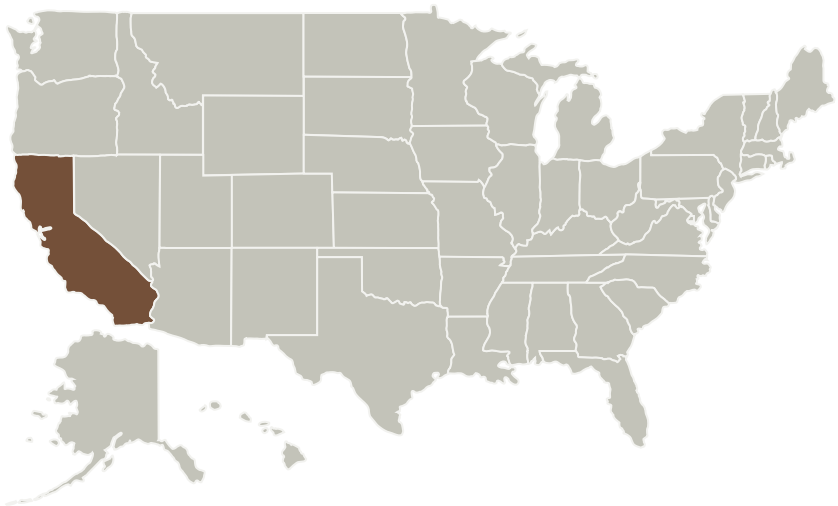
Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

California Institute of Technology (CalTech)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Sergio Pellegrino

Co-Investigator:

Kristina Hogstrom

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Organizations Performing Work	Role	Type	Location
California Institute of Technology(CalTech)	Lead Organization	Academia	Pasadena, California

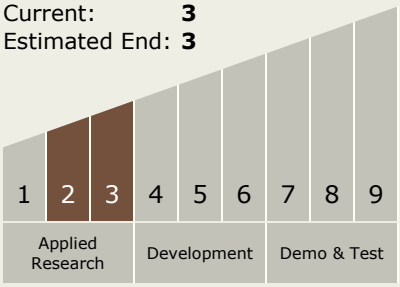
Primary U.S. Work Locations
California

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  - TX08.2 Observatories
    - TX08.2.2 Structures and Antennas